

Faster than light Bell telephone of Michalski transmits only noise

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Abstract

Motivated by pedagogical reasons we pinpoint the mistake in the recent claim, in quant-ph/9911016, that faster than light communication is possible.

In a recent e-print¹ it is claimed that faster than light communication is possible using EPR-Bell correlated photons. Having in mind younger students of the field, who may have some difficulties in quick spotting where the root of this erroneous claim is, we explicitly pinpoint it. The other motivation is the fact that exactly this type of mistake reappears from time to time in the discussions around the EPR paradox. Our reasoning has no originality at all, and is just an application of what one can find in many excellent textbooks.

Alice and Bob share an EPR correlated photon pair in the state

$$\frac{1}{\sqrt{2}}(|HH\rangle + |VV\rangle). \quad (1)$$

In such a state the probability of Alice to measure a photon in the state $\frac{1}{\sqrt{2}}(|H\rangle + |V\rangle)$ is $\frac{1}{2}$ not $1 - \epsilon$ (and this is totally independent of what method of measurement is employed). This is because the reduced density matrix of the photon at Alice side is

$$\begin{aligned} \text{Tr}_{Bob}[\frac{1}{\sqrt{2}}(|HH\rangle + |VV\rangle)\frac{1}{\sqrt{2}}(\langle HH| + \langle VV|)] = \\ \frac{1}{2}(\frac{1}{\sqrt{2}}(|H\rangle - |V\rangle))(\frac{1}{\sqrt{2}}(\langle H| - \langle V|)) + \frac{1}{2}(\frac{1}{\sqrt{2}}(|H\rangle + |V\rangle))(\frac{1}{\sqrt{2}}(\langle H| + \langle V|)). \end{aligned} \quad (2)$$

The above statement gives the final verdict for any attempts of using EPR correlations for faster than light communication. However, in the e-print of Michalski one can find one more mistake. The description of the multiphot beam splitter (fig. 1 of Michalski), in terms of mathematics, is correct. Nevertheless, the interpretation of the operation of the proposed optical device, within the context of quantum measurement is wrong.

The multiphot beam splitter of Michalski in the limit of n going to infinity indeed allows photons which enter it (via a chosen port) with arbitrary polarization to exit only either

¹ M. Michalski, quant-ph/9911016

by the + output port of the first beamsplitter, or by the + output of the last beamsplitter. Indeed the polarization state of the exiting photons is the same in both cases. However, in the interpretation of these facts Michalski completely ignores the following two basic facts. First, Michalski ignores which of the *two* events happens, i.e. behind which beamsplitter (the first one or the last one) the photon is registered. This is a wrong application of the quantum measurement postulates. The two events are macroscopically distinguishable²! The second fact is that Michalski forgets altogether that, according to his own calculations, *which of the two detectors fires is dependent on the initial state of the photon*. E.g., if $\alpha = \Omega$ the photon leaves always by the exit port + of the first beamsplitter, and if $\alpha = \Omega + \pi/2$ it leaves always via the exit port + of the last beamsplitter. In this way the device is indeed measuring (distinguishing) the polarization of the entering photons. When one forgets, like Michalski, about those facts, and is ignoring the information which of the two detectors fired, the device just measures the presence of a photon, but not its polarization.

When one sets, as Michalski does, $\Omega = \pi/4$, the multiport device of Michalski distinguishes perfectly between photons in the polarization states $\frac{1}{\sqrt{2}}(|H\rangle + |V\rangle)$ and $\frac{1}{\sqrt{2}}(|H\rangle - |V\rangle)$. In the first case the detector in the + exit port of the first beamsplitter fires, and in the second case the detector behind the + exit port of the last beamsplitter fires. I.e., as it was said in the very beginning the probability of Alice to measure a photon in the state $\frac{1}{\sqrt{2}}(|H\rangle + |V\rangle)$ is $\frac{1}{2}$ and not $1 - \epsilon$.

The fact that on exiting the device the photons are always in the same polarization state is completely irrelevant. One could replace the complicated device of Michalski by a single polarizing beamsplitter, no. 1 in the figure of Michalski, and place behind its – output a suitably orientated half-wave plate, which rotates the polarization state by $\pi/2$. Two detectors should observe the exit ports of this device. And each of them would see only photons in polarization state Ψ_+ . Such a simplified device has all the properties of the device of Michalski..., but in fact is just a plain photon polarization analyzer.

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²See e.g. R.P. Feynman, R.B. Leighton and M.L. Sands, *The Feynman Lectures on Physics*, (Addison-wesley, Reading, 1963), vol. 3, opening chapter